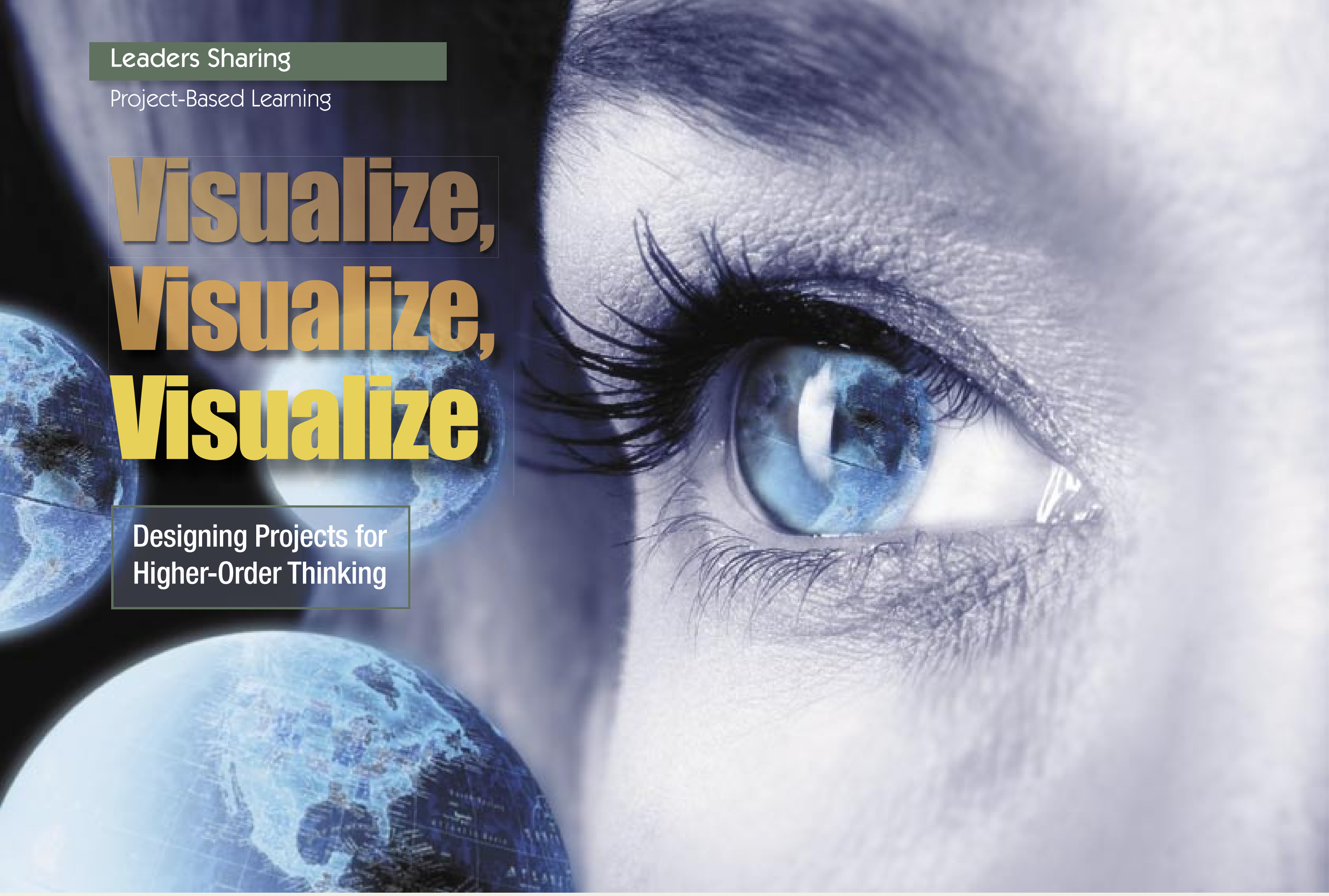
Visualize, Visualize, Visualize

Designing Projects for Higher-Order Thinking



Project-based learning provides a way of learning that seems to be particularly attractive to students who are struggling with conventional school assignments. In the study we described in our 2002 *Journal of Research on Technology in Education* article, Moments of Joy, we found that at-risk students became active learners willing to engage in cognitively challenging tasks when presented with a PBL opportunity.

Like many other educators, we believe PBL offers positive effects in cognitive, metacognitive, affective, and social domains. Good outcomes seem to occur almost without special effort: increased student involvement, persistence, and motivation; opening up a new conceptual space for students who begin to see themselves as learners; and benefits in understanding.

By Pearl Chen and Diane McGrath

Subject: Cognitive PBL

Standards: *NETS•T* II; *NETS•A* II (http://www.iste.org/standards)

However, the extent and nature of these effects vary greatly depending on the types of projects you create for your students. After engaging students in simple projects (hands-on learning projects), well suited for learning in the affective and social domains, you may want to increase the complexity of the projects to include specific cognitive and metacognitive learning goals. We will use the term *cognitive PBL* to describe projects that specifically aim to support these goals of higher-order thinking.

As teachers, we have all observed with a sense of frustration that students will successfully complete a learning process, but they do not seem to be able to use that knowledge effectively. Typical difficulties in the learning process are:

- *Conceptual difficulty:* students have difficulty when their naïve intuitions come into play
- *Foreign knowledge:* students have difficulty understanding multiple points of view
- *Knowledge transfer:* application of learning to new problems or situations
- *Self-regulation:* students have trouble taking charge of their own learning processes

We propose that with the use of cognitive PBL and appropriate technologies, we can move learners toward greater understanding and ability to apply that understanding.

Cognitive PBL, Knowledge Strategies, and Technology

In cognitive PBL, students not only process knowledge content in a deeper and more mindful manner, but also learn valuable thinking skills, something about their learning processes, and about how to learn. The goal in cognitive PBL is to move students from simple knowledge-telling to complex knowledge-transforming by deliberately using explicit cognitive strategies. In contrast to simple projects that may be more transparent and regulated by teachers, cognitive PBL involves students in complex tasks that require considerable effort and exercise of self-regulatory and judgment skills with appropriate teacher guidance.

We believe that constructivist and creative use of technology can be very effective in helping students escape from their passive and habitual learning patterns—the first step necessary toward developing mature cognitive strategies.

Several strategies and technologies exist for each of the four problem areas we described. To help you choose appropriate tools, we use examples based on the categories proposed by Bruce and Levin: tools for inquiry, communication, construction, and expression. (***Editor's note:*** See this and other resources on p. 57.)

The strategies we suggest in Table 1. (p. 56) are based on two important concepts that emphasize making thinking visible: cognitive apprenticeships and computer-supported intentional learning environments (CSILEs). The idea behind cognitive apprenticeships is to take the scaffolding and authentic participation portions of a traditional apprenticeship and bring those stategies into the school setting. Teaching methods involved in cognitive apprenticeships can include modeling, coaching, scaffolding, articulation, reflection, and more.

In CSILEs, the learning environment becomes knowledge centered—everyone contributes to the growing knowledge of the entire classroom. Much more in-depth information on these ideas is in a supplement available on McGrath's PBL Web site.

The focus of cognitive PBL should be on guiding learners to go beyond information given. This strategy helps learners develop more complex, higher-level cognitive processes and experience cognitive emotions that develop into intellectual passions. One common thread that runs through the research on higher-order thinking is the idea of helping learners gain conscious access to their own minds. As long-time Harvard educational researcher D. N. Perkins, in his book *The Mind's Best Work*, has reminded us, "We have more access to our minds than we might have thought. With that greater access might come greater opportunity to tinker." This is why it is so important to make thinking visible—you are able to talk about it, think about your understanding, and fine-tune or reorganize your thinking. It is important to make both the learner's thinking process observable to him/herself and to the teacher or expert, and to help the learner to observe a teacher's or an expert's thinking process.

There are many strategies for making thinking visible.

Asking students to speak their minds or write down their thinking process, and then identifying patterns in their thoughts and gaps in their understandings. A program such as Inspiration with an accompanying note for each symbol can be used to explain reasoning and thinking steps. Both concept mapping and hypermedia authoring tools can be used to help students easily reorganize and fine-tune their representations. Figure 1 is an example of such a concept map on the topic of water.

Using technology constructively in a way that pays special attention to cognitive principles. This strategy can provide greater flexibility for students to confront the discrepancies of their understanding for conceptually difficult knowledge and for defending alternative points of view for foreign knowledge.

Encouraging learners to deliberately practice effective thinking strategies. Some general principles might be enough to do the trick. For example, to promote inventive thinking, Perkins says that principles given to the students should be "as easy as a recipe for boiling water" to alert them to certain methods and re-shape their

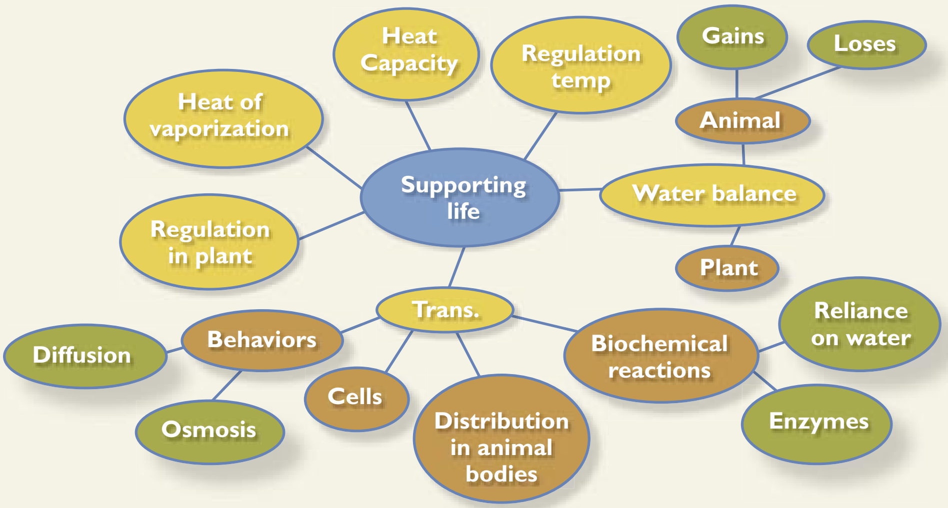


Figure 1. An example of using a concept map to fine-tune concepts during knowledge construction.

Table 1. Knowledge Strategies and Appropriate Technologies for Designing Cognitive PBL Projects

Knowledge Strategies, Scaffolding Techniques	Examples of Appropriate Technologies
Learner Difficulty: *Conceptually Difficult*	
• Modeling: given a model, ask learners to "rediscover" and interpret in an active and exploratory way. • Scaffolding: find out misconceptions and look for internal patterns. • Articulation and reflection: organize knowledge actively, make knowledge-construction activities overt, use presentation and peer critiquing.	Tools for inquiry (theory building): • Model exploration and simulation toolkits • Visualization software • Virtual reality environments • Data modeling—defining categories, relations, representations (e.g., Stella) • Procedural models, mathematical models • Knowledge representation: semantic network, outline tools (e.g., Inspiration)
Learner Difficulty: *Foreign*	
• Design learning tasks that require identifying and explaining or defending alternative points of view. • Encourage examination of existing knowledge. • Encourage multiple passes through information. • Treat gaps in knowledge in a positive way. • Support varied ways for students to organize their knowledge.	Tools for communication: • Asynchronous and synchronous computer conferencing (e.g., e-mail, iSight/iChat, conferencing on the Web [see Resources]) • Student-created hypertext environments Tools for inquiry: • Knowledge representation: semantic network, outline tools (e.g., Inspiration) • Internet for research Tools for expression: • Multimedia composition
Learner Difficulty: *Knowledge Transfer and Application*	
• Design projects to build cognitive and metacognitive capabilities. • Explicitly demonstrate and discuss how the knowledge gained in this project may be applied in other projects and domains. • Facilitate transfer of knowledge across contexts by applying knowledge across disciplines.	Tools for communication (collaboration): • Collaborative data environments • Group decision support systems • Shared document preparation. Tools for inquiry: • Knowledge integration (e.g., hypermedia authoring) • Knowledge representation: semantic network, outline tools (e.g., Inspiration) • Internet for research
Learner Difficulty: *Self-Regulatory Learning*	
• Teach students to think like experts and encourage learning strategies other than rehearsal. • Make thinking visible and maintain attention to cognitive goals rather than task goals. • Make learning processes visible and provide relevant feedback on the processes. • Give learners legitimate role in the community of learners. Give students more responsibility for contributing to each other's learning. • Use a real audience to evaluate their work. • Provide opportunities for reflection and individual learning styles.	Tools for inquiry: • Knowledge representation: semantic network, outline tools (e.g., Inspiration) • Online inquiry tools (e.g., WISE [see Resources]) • Internet for research Tools for construction: • Robotics kits Tools for expression: • Hypermedia authoring • Multimedia composition

behaviors to meet the demands of the task. His examples of good principles include such things as practicing in context, and when confused, employing concrete representations.

Modeling, coaching, and scaffolding to enable learners to observe a teacher's or an expert's thinking process. Learners can refine their understanding through articulation and compare their strategies to those used by the teacher/expert through reflection. Eventually, learners are pushed to the stage of exploration in which they independently use the expert strategies in framing and solving the problem. Technology can be used for modeling, scaffolding, reflection, promoting intentional and exploratory use of thinking strategies, and restructuring.

For example, in our study of a project that used hypermedia for high school students to represent their understanding of water concepts, modeling was provided through a hypermedia document we created to teach hypermedia concepts (links, nodes, paths, and so on). This allowed students to explore the hypermedia environment while learning the concepts that made such an environment possible. Coaching was provided through discussion of hypermedia concepts and demonstration of examples and techniques for designing hypermedia. The teacher coached students in taking notes as well as summarizing and synthesizing information by modeling his own "brain net" on an overhead projector while reading a passage from the textbook. At the same time, he also helped students in developing associative ways of thinking by demonstrating the techniques of concept mapping on an overhead projector. Scaffolding was provided through a designer's notebook to support students' linking of ideas and organization of the knowledge content. Finally, articulation and reflection were provided through a continuous process of peer critiquing and a public presentation of student project.

Using technology to provide a trace of students' tuning, organizing, and reorganizing process during knowledge construction. Students can save their projects at the end of each project session to provide electronic records of their thinking process. Each project's structural representations or outlines then can be captured into image files to trace changes attempted by students, and to identify faulty construction or misrepresentation of concepts. This portfolio idea enables students, parents, and teachers to follow the development of understanding and to discuss problems along the way. To promote intentional use of thinking strategies, criteria for assessing both domain knowledge and cognitive skills should be clear and available to the students. You may also want to include your students in brainstorming and making decisions about assessment criteria.

In sum, a general rule of thumb for designing cognitive PBL is visualize, visualize, and visualize the thinking process.

Conclusion

What we have been proposing is an approach to PBL in which the goal is to focus on thinking, making thinking processes visible to teacher and students. Ideas and understandings can be evaluated and revised much more easily if there is something to see, something that can be shared, discussed, and revised. We have tried to give you both a conceptual framework for understanding exactly what the learning issues are and some examples of principles, guidelines, and technologies that can assist you in your cognitive PBL projects.

Write and tell us what strategies you have tried to encourage higher-order thinking, and let us know if any of these ideas are helpful in your projects.

Resources

For links from this and other PBL articles in this series, go to Diane McGrath's PBL Web site at http://coe.ksu.edu/PBL/.

Supplement to these articles: http://coe.ksu.edu/PBL/supplement1204.html

Articles

Bruce, B. C., & Levin, J. A. (1997). Educational technology: Media for inquiry, communication, construction, and expression. *Journal of Educational Computing Research, 17*(1), 79–102. Available: http://www.lis.uiuc.edu/%7Echip/pubs/taxonomy/.

McGrath, D., Sylvester, A., & Chen, P. (1999). *At risk: Traditional teaching. Bring in the learners and the Web!* Presented at the National Educational Computing Conference, Atlantic City, NJ, June 22–24. Available: http://coe.ksu.edu/mcgrath/NECC/NECC99.htm.

Perkins, D. (2003, Dec.). Making thinking visible. *New Horizons for Learning.* Available: http://www.newhorizons.org/strategies/thinking/perkins.htm.

Web Sites on Making Thinking Visible

Concord Consortium's Making Thinking Visible—Promoting Students' Model Building and Collaborative Discourse, an NSF project: http://mtv.concord.org/

Harvard's Making Learning Visible: http://www.pz.harvard.edu/mlv/

Thinkofit's Conferencing on the Web: http://www.thinkofit.com/webconf/

WISE (Web-based Inquiry Science Environment): http://wise.berkeley.edu/. (You must register to use these online tools.)

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